

Clinical Study

Carbon Dioxide Insufflation in Colonoscopy Is Safe: A Prospective Trial of 347 Patients

M. Geyer,¹ U. Guller,^{2,3} and Ch. Beglinger⁴

¹ Gastroenterologie Wettingen, Rosengartenstrasse 2, 5430 Wettingen, Switzerland

² Department of Oncology, Kantonsspital, 9007 St. Gallen, Switzerland

³ Department of Visceral Surgery and Medicine, University Hospital Bern, 3010 Bern, Switzerland

⁴ Department of Gastroenterology, University Hospital, 4031 Basel, Switzerland

Correspondence should be addressed to M. Geyer, geyer@gastroenterologie-wettingen.ch

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Available evidence suggests that the use of CO₂ insufflation in endoscopy is more comfortable for the patient. The safety of CO₂ use in colonoscopy remains contentious, particularly in sedated patients. The objective of the present prospective trial was to assess the safety of CO₂ colonoscopies. *Methods.* 109 patients from our previous randomized CO₂ colonoscopy study and an additional 238 subsequent consecutive unselected patients who had a routine colonoscopy performed in a private practice were enrolled from April 2008 through September 2008. All but 2 patients were sedated. All patients were routinely monitored with transcutaneous CO₂ measurement. Volumes of CO₂ administered were correlated with capnographic measurements from transcutaneous monitoring. *Results.* Of the 347 patients examined, 57% were women; mean (SD) age of participants was of 60.2 years (12.8). Mean propofol dosage was 136 mg (64 mg). Mean CO₂ values were 34.7 mm Hg (5.3) at baseline, 38.9 mm Hg (5.5) upon reaching the ileum, and 36.9 mm Hg (5.0) at examination's end. Mean maximum increase of CO₂ was 4.5 mm Hg (3.6). No correlation was observed between volume of CO₂ administered and increase in level of CO₂ (correlation coefficient: 0.01; *P* value: 0.84). No complications were observed. *Conclusions.* The present prospective study, which was based on one of the largest sedated patient sample reported to date in this setting, provides compelling evidence that CO₂ insufflation in colonoscopy is safe and unassociated with relevant increases in transcutaneously measured levels of CO₂.

1. Background

For almost 2 decades, CO₂ insufflation with carbon dioxide (CO₂) has been widely used in laparoscopic surgery. In contrast, insufflation with room air has remained the standard of care in the vast majority of endoscopy centers in both Europe and North America. Unfortunately, many patients still experience pain and discomfort after colonoscopy with room air insufflation. Studies [1–5] and one review [6] indicate that insufflation with CO₂ can reduce periprocedural pain in different endoscopic settings (e.g., endoscopic retrograde cholangio-pancreatography [7], balloon enteroscopy [8], and endoscopic submucosal dissection [9]). However, in the setting of colonoscopy, current scientific data with regard to the safety of CO₂ insufflation are limited. Small patient populations have characterized most studies, including those

with sedated patients, and many physicians remain concerned that CO₂ insufflation might lead to CO₂ retention. In a previous randomized, controlled, double-blinded trial, we randomly allocated 219 patients to colonoscopy with CO₂ versus room air, patients in the CO₂ group experienced significantly less pain and bloating and a higher overall satisfaction score [10]. However, this study was not designed to definitively demonstrate the safety of CO₂ insufflation in colonoscopy. In the present study, we sought to prospectively assess the safety of CO₂ colonoscopy in a larger sample of patients.

2. Patients and Methods

This trial included all 109 patients from our previous CO₂ colonoscopy study [10] plus 238 subsequent, consecutive,

nonselected, patients who had a routine colonoscopy performed in a private Swiss gastroenterology practice and were enrolled from April 2008 through September 2008. All patients who were deemed medically fit for an ambulatory colonoscopy were included in this study. In order to maximize the generalizability (external validity) of our study, we did not initially apply exclusion criteria, although one exclusion criterion emerged (due to a small earlap, CO₂ measurement was not possible in 4 patients, which were excluded). All colonoscopies were done by the first author (M. G.) and carried out with standard Pentax endoscopes (EC-3885K and EC-380FKp) (Pentax Medical, Pentax of America, Inc., Montvale, NJ, USA) with an EPK 1000 processor. For CO₂ insufflation, the CO₂-Efficient Insufflator device (EZEM Company, Westbury, NY, USA) was used. The insufflator was connected to a 10-litre CO₂ bottle and supplied over a tubing set connected with a branch connection to the water bottle tube, which was itself directly connected to the endoscope. The flow rate (basal flow rate 0.5 L/min, increasing to 3 L/min maximum) can be controlled on demand over the standard air valve. Oxygen was delivered to patients if the saturation dropped below 90% at a flow rate of 4 liters per minute.

All but 2 patients were sedated with propofol using standard procedures previously described [11]. The total dose of propofol was registered for later analysis. A level of conscious sedation ("moderate sedation") was targeted. All patients were routinely monitored with transcutaneous CO₂ measurement on the ear, with the exception of those patients who were excluded due to insufficient earlap ($n = 4$). CO₂ measurement was performed with the SenTec capnograph (SenTec AG, 4106 Therwil, Switzerland) as described by Heuss et al. [12]. Our measurement technique followed that recommended by SenTec; internal validation was not performed as the system has been previously extensively validated [12–14]. Sensors were calibrated according to mandatory procedure and placed on the earlap after cleaning with 70% isopropyl alcohol solution and application of contact liquid on the sensor membrane.

In previous validation studies, correlation of partial pressure of CO₂ (paCO₂) and transcutaneous CO₂ measurement was as follows: $r = 0.92$; intraclass correlation coefficient [ICC] = 0.92; for arterial saturation of oxygen (SaO₂/SpO₂), $r = 0.74$; ICC = 0.73 [14]. Data for continuous transcutaneous CO₂ measurements were analyzed, as were baseline characteristics including age, propofol use, and CO₂ volume administered. To ensure validity of our measurements, we analyzed and compared the 238 consecutive patients separately, with the 109 patients derived from our earlier CO₂ study using an unpaired t -test. Additionally the correlation of the insufflated amount of CO₂ with a possible increase of transcutaneously measured CO₂ was assessed using Spearman correlations. Statistical analyses were performed using SPSS, v. 11.0 (IBM Corp., Armonk, NY, USA).

3. Results

The first sample of 109 patients who received CO₂ insufflation for colonoscopy was drawn from our previous

TABLE 1: Results (mean \pm SD)¹.

	1st sample ($n = 109$)	2nd sample ($n = 238$)	All ($n = 347$)
Sex, female	62%	55%	57%
Propofol (mg)	134 \pm 56	137 \pm 68	136 \pm 64
CO ₂ start (mm Hg)	33.4 \pm 4.7	35.4 \pm 5.4	34.7 \pm 5.3
CO ₂ ileum (mm Hg)	37.3 \pm 5.2	39.6 \pm 5.5	38.9 \pm 5.5
CO ₂ end (mm Hg)	35.2 \pm 4.3	37.7 \pm 5.1	36.9 \pm 5.0
Amount CO ₂ (L)	51 \pm 14	47 \pm 15	48 \pm 15

¹All P values > 0.05 .

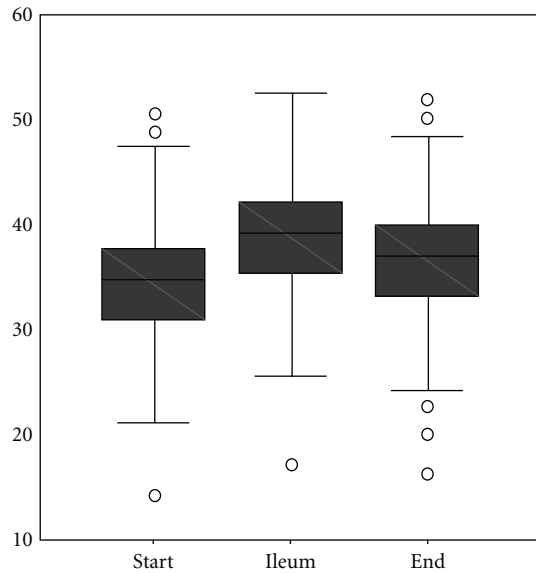
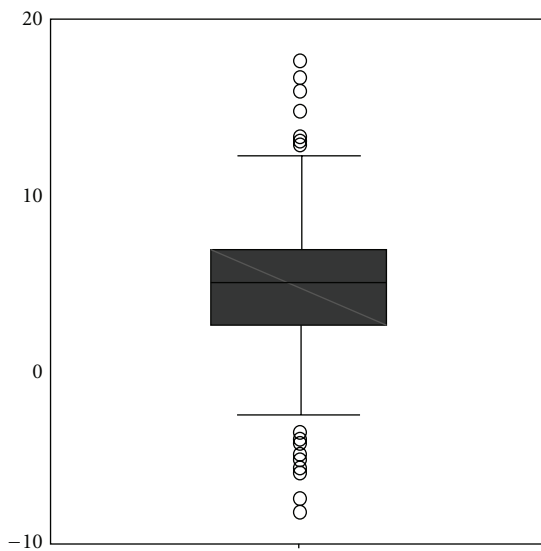
study, which was conducted from April to June of 2008. All subsequent patients referred for colonoscopy at this single practice were routinely examined with CO₂, with the result that from June 2008 through September 2008, an additional 238 patients (second sample) were examined using CO₂ insufflation, for a final study population of 347. Of the 347 patients examined, 198 (57%) were female; the mean (SD) age was 60 years (12.8). Mean (SD) propofol dosage was 136 mg (64) (Table 1); mean (SD) duration of endoscopy procedures was 24 minutes (7.5). All but 2 patients in the second sample were sedated. Mean (SD) value for baseline CO₂ measurement was 34.7 mm Hg (5). Mean (SD) pressure of CO₂ recorded reaching the ileum was 38.9 mm Hg (5) and 36.9 mm Hg (5) at the end of the examination (Figure 1). Mean maximum increase of CO₂ pressure was 4.4 mm Hg (Figure 2).

Four patients in the second sample experienced transient pCO₂ values in excess of 50 mm Hg (three when reaching the ileum and one at the end of the examination), but these patients showed no signs of respiratory distress or O₂ desaturation and O₂ substitution was not deemed necessary. These four patients did not receive a higher propofol dosage or volume of CO₂ insufflated.

Among the total study sample, no correlation was observed between volume of CO₂ administered and an increase of CO₂ (correlation coefficient: 0.01; P -value: 0.84) (Figure 3). Parameters did not significantly differ between the first and second samples. None of the patients required ventilation or mechanical airway support, and no other complications (bleeding, perforation, loss of consciousness, hospital admission) were observed.

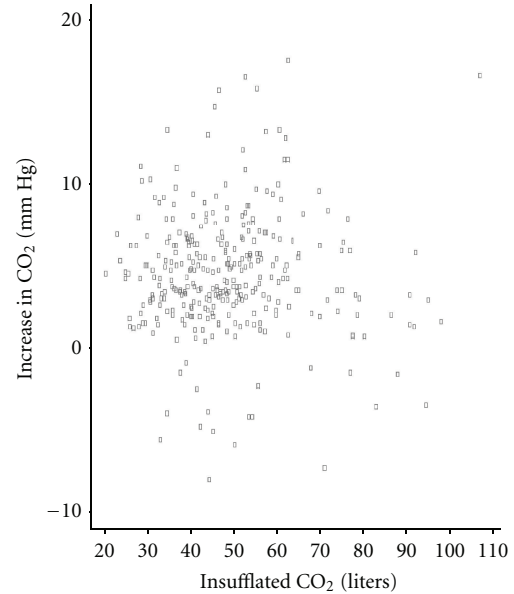
4. Discussion

The present prospective study, which was based on one of the largest sample of sedated patients to date, provides compelling evidence that CO₂ insufflation colonoscopy is safe and is not associated with an increase in transcutaneously measured CO₂ or with adverse respiratory effects. Our findings add to mounting scientific evidence demonstrating the safety and superiority of CO₂ colonoscopy over room air [6, 10]. Given these findings, we believe that CO₂ colonoscopy should be considered the procedure of choice.

FIGURE 1: CO₂ values over time (mm Hg).FIGURE 2: Increase in CO₂ (mm Hg).

Although CO₂ insufflation has been used for different endoscopic procedures [1–9] and was found to be associated with less postprocedural pain and bloating [10, 15], most endoscopy units continue to use room air for screening colonoscopies and are unaware of the benefits of this relatively new technique [16].

In our first double-blinded randomized study—hitherto the largest reported sample of sedated and CO₂ monitored patients—239 patients were randomly allocated in a 1:1 ratio to colonoscopy with CO₂ versus room air. This study, which represented the first examination of sedated, unselected, and consecutive patients in this setting, yielded encouraging results: no difference in transcutaneous CO₂ values was observed with continuous capnography between

FIGURE 3: Correlation of CO₂ change and insufflated CO₂ volume.

groups, and there was no evidence of advanced hypercapnia as a possible problem with this technique [10]. However, we felt that this initial experience from our group needed to be confirmed in a study with larger sample size. By incorporating patients randomized to CO₂ insufflation in that previous study and an additional 238 consecutive patients, we achieved an even larger patient population, providing compelling evidence for the safety of CO₂ insufflation in sedated and monitored patients undergoing colonoscopy. Only 4 patients experienced a partial pressure of CO₂ in excess of 50 mm Hg (max. paCO₂ 52.8 mm Hg).

Our study shows that sedated patients had a small increase in CO₂ during colonoscopy until the terminal ileum was reached, after which CO₂ levels fell. We speculate from these observations that sedation per se, but not CO₂ insufflation in particular, appears to be the primary cause of the observed CO₂ increase during colonoscopy.

Many patients with severe chronic obstructive pulmonary disease (COPD) experience CO₂ retention, an inherent phenomenon of this disease. Until now, no studies have been performed to assess whether CO₂ is also safe to use in this high-risk population. But although COPD patients included in our study suffered no relevant adverse outcomes, they constituted only a small percentage of the study population and larger studies of CO₂ insufflation in patients with COPD should be performed to confirm its safety in this subset of patients.

A particularly noteworthy finding of this study is the lack of correlation between volume of insufflated CO₂ and the increase of CO₂ as measured by transcutaneous monitoring. Because CO₂ is very quickly exhaled, paCO₂ never reached clinically toxic value. It might be influenced more by individual factors not yet fully understood than by the amount of insufflated CO₂.

Because CO₂ is absorbed into the bloodstream 150 times faster than room air and also exhaled with an elimination of 0.2 L per minute [17], higher volumes of gas (e.g., 51 L [± 14 L]) are usually needed when using CO₂ for colonoscopy insufflation, compared with room air [18]. Some physicians who are already using CO₂ insufflation for colonoscopy believe that briefly switching from CO₂ to room air to obtain a faster and better colonic distension can be useful in certain circumstances. This may be due to the fact that the flow rates of all commercial available CO₂ insufflators are still below the usual rates achieved with air insufflators.

From a practical point of view, there are no clinically relevant problems in handling CO₂ insufflation with modern insufflators; further, we believe that no safety concerns remain in patients devoid of COPD.

5. Conclusion

The present prospective study, which was based on one of the largest sedated patient sample reported to date, provides compelling evidence that colonoscopy with CO₂ insufflation is safe in patients devoid of COPD. Neither a relevant increase in transcutaneously measured CO₂ nor adverse respiratory effects were detected.

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References

- [1] M. Bretthauer, A. B. Lynge, E. Thiis-Evensen, G. Hoff, O. Fausa, and L. Aabakken, "Carbon dioxide insufflation in colonoscopy: safe and effective in sedated patients," *Endoscopy*, vol. 37, no. 8, pp. 706–709, 2005.
- [2] M. Bretthauer, E. Thiis-Evensen, G. Huppertz-Hauss et al., "NORCCAP (Norwegian colorectal cancer prevention): a randomised trial to assess the safety and efficacy of carbon dioxide versus air insufflation in colonoscopy," *Gut*, vol. 50, no. 5, pp. 604–607, 2002.
- [3] A. M. J. Hussein, C. I. Bartram, and C. B. Williams, "Carbon dioxide insufflation for more comfortable colonoscopy," *Gastrointestinal Endoscopy*, vol. 30, no. 2, pp. 68–70, 1984.
- [4] K. Sumanac, I. Zealley, B. M. Fox et al., "Minimizing postcolonoscopy abdominal pain by using CO(2) insufflation: a prospective, randomized, double blind, controlled trial evaluating a new commercially available CO(2) delivery system," *Gastrointestinal endoscopy*, vol. 56, no. 2, pp. 190–194, 2002.
- [5] J. C. H. Wong, K. K. Yau, H. Y. S. Cheung, D. C. T. Wong, C. C. Chung, and M. K. W. Li, "Towards painless colonoscopy: a randomized controlled trial on carbon dioxide-insufflating colonoscopy," *ANZ Journal of Surgery*, vol. 78, no. 10, pp. 871–874, 2008.
- [6] E. S. Dellon, J. S. Hawk, I. S. Grimm, and N. J. Shaheen, "The use of carbon dioxide for insufflation during GI endoscopy: a systematic review," *Gastrointestinal Endoscopy*, vol. 69, no. 4, pp. 843–849, 2009.
- [7] M. Bretthauer, B. Seip, S. Aasen, M. Kordal, G. Hoff, and L. Aabakken, "Carbon dioxide insufflation for more comfortable endoscopic retrograde cholangiopancreatography: a randomized, controlled, double-blind trial," *Endoscopy*, vol. 39, no. 1, pp. 58–64, 2007.
- [8] D. Domagk, M. Bretthauer, P. Lenz et al., "Carbon dioxide insufflation improves intubation depth in double-balloon enteroscopy: a randomized, controlled, double-blind trial," *Endoscopy*, vol. 39, no. 12, pp. 1064–1067, 2007.
- [9] S. Yutaka, U. Toshio, M. Takahisa et al., "A pilot study to assess the safety and efficacy of carbon dioxide insufflation during colorectal endoscopic submucosal dissection with the patient under conscious sedation," *Gastrointestinal Endoscopy*, vol. 65, no. 3, pp. 537–542, 2007.
- [10] M. Geyer, U. Guller, and C. Beglinger, "Carbon dioxide insufflation in routine colonoscopy is safe and more comfortable: results of a randomized controlled double-blinded trial," *Diagnostic and Therapeutic Endoscopy*, vol. 2011, Article ID 378906, 6 pages, 2011.
- [11] L. T. Heuss, P. Schnieper, J. Drewe, E. Pflimlin, and C. Beglinger, "Risk stratification and safe administration of propofol by registered nurses supervised by the gastroenterologist: a prospective observational study of more than 2000 cases," *Gastrointestinal Endoscopy*, vol. 57, no. 5, pp. 664–671, 2003.
- [12] L. T. Heuss, P. N. Chhajed, P. Schnieper, T. Hirt, and C. Beglinger, "Combined pulse oximetry/cutaneous carbon dioxide tension monitoring during colonoscopies: pilot study with a smart ear clip," *Digestion*, vol. 70, no. 3, pp. 152–158, 2004.
- [13] R. Roediger, B. Beck-Schimmer, O. M. Theusinger et al., "The revised digital transcutaneous PCO₂/SpO₂ ear sensor is a reliable noninvasive monitoring tool in patients after cardiac surgery," *Journal of Cardiothoracic and Vascular Anesthesia*, vol. 25, no. 2, pp. 243–249, 2011.
- [14] C. Domingo, E. Canturri, M. Luján, A. Moreno, H. Espuelas, and A. Marín, "Transcutaneous measurement of partial pressure of carbon dioxide and oxygen saturation: validation of the SenTec monitor," *Archivos de Bronconeumologia*, vol. 42, no. 5, pp. 246–251, 2006.
- [15] J. Wu and B. Hu, "The role of carbon dioxide insufflation in colonoscopy: a systematic review and meta-analysis," *Endoscopy*, vol. 44, no. 2, pp. 128–136, 2012.
- [16] F. Janssens, J. Deviere, P. Eisendrath, and J. M. Dumonceau, "Carbon dioxide for gut distension during digestive endoscopy: technique and practice survey," *World Journal of Gastroenterology*, vol. 15, no. 12, pp. 1475–1479, 2009.
- [17] H. A. Saltzman and H. O. Sieker, "Intestinal response to changing gaseous environments: normobaric and hyperbaric observations," *Annals of the New York Academy of Sciences*, vol. 150, no. 1, pp. 31–39, 1968.
- [18] M. Bretthauer, G. S. Hoff, E. Thiis-Evensen, G. Huppertz-Hauss, and E. Skovlund, "Air and carbon dioxide volumes insufflated during colonoscopy," *Gastrointestinal Endoscopy*, vol. 58, no. 2, pp. 203–206, 2003.

